

# User Guide

# EpiSensor

## Force Balance Accelerometer

Model FBA ES-U

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# Safety

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## Symbols & Terms

The following symbols may appear on Kinometrics equipment or in this manual.



When you see this symbol, *pay careful attention*. Refer to the similarly marked, relevant part of this manual before servicing the instrument.



This symbol means a *low-noise earth ground*. The noted item should be grounded to ensure low-noise operation, and also to serve as a ground return for EMI/RFI and transients. Such a ground *does not work as a safety ground* for protection against electrical shock!



This symbol means an alternating current (AC) power line.



This symbol means a direct current (DC) power line derived from an AC power line.



This symbol indicates an electrostatic sensitive device (ESD), meaning that when handling the marked equipment you should observe all standard precautions for handling such devices.

These safety-related terms appear in this manual:

**Note:** statements identify information that you should consider before moving to the next instruction or choice.

**Caution** statements identify conditions or practices that could result in damage to the equipment, the software, or other property.

**WARNING!** statements identify conditions or practices that could result in personal injury or loss of life.

---

## Specific Precautions

Follow the precautions below to ensure your personal safety and prevent damage to the EpiSensor.

### POWER SOURCE

The EpiSensor must be supplied with power either from a recorder or from a customer-supplied  $\pm 12\text{V}$  or  $\pm 15\text{V}$  power supply (or a  $+ 12\text{V}$  supply for the single-supply option).

If you plan to power the EpiSensor from a recorder, connect the recorder to a power supply/charger supplied by Kinometrics, as described in each recorder's user manual.

To supply power directly to the EpiSensor, you need a low-noise, regulated  $\pm 12\text{V}$  or  $\pm 15\text{V}$  power supply (or a  $+ 12\text{V}$  supply for the single-supply option) that is safely grounded and meets all applicable local regulations. The EpiSensor will be damaged if the power is connected with the wrong polarity.

### USER-SUPPLIED POWER/CHARGING SYSTEM

If you supply your own power/charging system, be sure that the system provides the correct voltage and current required by the EpiSensor under all operating conditions. You are responsible for the safety of your charging system. If you get power from the mains supply, be sure you have supplied adequate grounding for all the equipment. If you supply your own batteries, follow the manufacturer's safety recommendations.

### SENSOR GROUNDING AND CABLING



In some cases the EpiSensor will be a long distance from the recorder. In these installations it is possible, due either to faulty AC wiring or extremely high earth-return currents, for a high potential difference to exist between the grounds at the two locations. When the cable is grounded at one end a potentially lethal voltage can exist between the other end of the cable and ground. Consider this danger during installation and get help from a qualified electrician if this danger exists.

### DO NOT OPERATE IN EXPLOSIVE ATMOSPHERE

The EpiSensor provides *no explosive protection* from static discharges or arcing components. *Do not* operate the equipment in an atmosphere where explosive gases are present.

# Sicherheit

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## Symbole & Begriffe

Diese *Symbole* können auf Kinematics Geräte oder in diesen Manuel erscheinen:



Bedeutet *Achtung!* Wenn sie dieses Symbol auf ein Gerät sehen, muss den gleich markierten Teil dieses Manuels beachtet werden. *Bevor* irgend eine Unterhaltsarbeit angefangen wird, *muss* dieser Teil des Manuels gelesen werden. Wenn Sie dieses Symbol sehen, bitte besondere Achtung geben.



Bedeutet Erdung. Das erwaente Teil sollte geerdet werden, um eine "low-noise" operation zu versichern, und dann auch als Erdung für EMI/ FRI und Transienten und solch eine Erdung wird *nicht als Sicherheit gegen* elektrischen Schock dienen!



Bedeutet *Wechselstromzufuhr* (AC) mit Elektroschock Gefahr.



Bedeutet Gleichstromzufuhr von AC Versorgung herkommend.



Bedeutet *Elektrostatisch Sensibeles Element (ESD)* für dessen Handhabung alle vorbeugende Vorsichtsmassnahmen genommen werden müssen.

Folgende *Darstellungen* werden in diesen Manuel erscheinen:

**Note:** Darstellung welche Informationen Sie erhalten, die besonders beachtet werden müssen, bevor sie zum nächsten Schritt gehen.

**Caution:** Darstellung bei dem die Missachtung in der Regel Gefahr für Defekte und Störungen im Gerät, Programm oder Zubehör besteht.

**WARNING!** Darstellung bei dem die Missachtung in der Regel Verletzungen – oder Lebensgefahr besteht.

## Spezielle vorbeugende Massnahmen

Alle vorbeugende Massnahmen müssen beachtet werden. Für Ihre persönliche Sicherheit, und um Schäden im EpiSensor zu vermeiden.

### STROMVERSORGUNG

Die EpiSensor muss entweder mit Strom von einem Accelerograph oder Ihrer eigenen Stromquelle  $\pm 12-15$  V versorgt werden.

Sollten Sie planen, die EpiSensor mit Strom von einem Recorder zu versorgen, verbinden Sie den Recorder mit unserem Kinematics Stromladegerät, wie es in unserem "User Manuel" beschrieben ist.

Um die EpiSensor direkt mit Strom zu versorgen, müssen Sie ein Ladegerät  $\pm 12-15$  V, welches mit allen Sicherheitsbedingunge ausgestattet ist, benutzen.

### OPTIONELLES STROMVERSORGUNGS/LADEGERÄT

In manchen Fällen wird die EpiSensor eine lange Strecke von dem Recorder entfernt Sein, wo es dann möglich sein könnte, dass durch beschädigte AC-Wiring oder Hohe Erdbewegungen, ein Spannungsunterschied besteht. Es ist daher unbedingt notwendig, dass alle angeschlossenen Instrumente am gleichen Spannungspotential geerdet sind. Bitte folgen Sie den vom Hersteller gegebenen Empfehlungen.

### VERKABLUNG UND ERDUNG VOM SENSOR

Wenn das Kabel an einem End geerdet ist, kann ein verhältnismässig grosser Unterschied in der Voltage bestehen, welcher sehr gefährlich ist. Bitte beachten Sie Diese Gefahr und wenn nötig, ziehen Sie das Gutachten eines qualifizierten Elektrikers Ein.

### NICHT IN EXPLOSIONSGEFÄHRDETE UMGEBUNG GEBRAUCHEN

Der EpiSensor hat keinen Explosions-schutz von statischen Entladungen oder funkgefährdeten Bauteilen. Benutzen sie die Geräte nicht in Umgebungen mit explosiven Gasen.

# Seguridad

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## Símbolos & Términos

Estos *símbolos* podrían aparecer en los equipos Kinematics o en este manual:



Significa *poner atención!* Cuando Usted vea este símbolo en el instrumento, referirse a las partes de este manual marcadas similarmente. *Antes* de intentar cualquier servicio en este instrumento, Usted *tiene que* leer las partes relevantes de este manual. Si Usted ve este símbolo, ponga atención cuidadosamente.



Significa un *polo a tierra de bajo ruido*. El ítem referido debe estar polarizado a tierra para asegurar la operación a bajo ruido y además sirve como un retorno a tierra para el EMI/RFI y transitorios. Tal polo a tierra no trabaja como un polo a tierra de seguridad para protección contra choques eléctricos!



Significa una línea de energía de Corriente Alterna (AC).



Significa una línea de energía de Corriente Directa derivada de una línea de energía AC.



Significa una *Unidad Sensitiva a Electrostática (Electrostatic Sensitive Device ESD)*, indicando que usted debe tener cuidado y observar todas las precauciones para el manejo de tales unidades.

Estos *términos* aparecerán en este manual:

**Note:** sentencias identificando información que Usted debe considerar cuidadosamente antes de dirigirse a la siguiente instrucción u opción.

**Caution:** sentencias identificando condiciones o practicas que podrían resultar en daño del equipo, el software u otra propiedad.

**WARNING!** sentencias identificando condiciones o practicas que podrían resultar en una lesión personal o la perdida de la vida.

Los últimos dos términos mencionados arriba podrían también aparecer en el equipo Kinometrics que Usted ha comprado, pero no necesariamente — indiferentemente, Usted debe definitivamente tomar notas serias de las precauciones y advertencias en este manual.

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## Precauciones Específicas

Siga las precauciones a continuación para garantizar su seguridad personal y prevenir daños al EpiSensor.

### FUENTE DEL PODER

El EpiSensor debe ser alimentado con energía ya sea desde un registrador o desde una fuente de  $\pm 12-15V$  provista por el usuario.

Si usted planea alimentar el EpiSensor desde un registrador, conecte el registrador a una fuente de poder/cargador suministrado por Kinometrics, como se describe en cada manual del usuario para el registrador.

Para suministrar energía directamente al EpiSensor, usted necesita una fuente de poder de bajo ruido y regulado  $\pm 12-15V$ , el cual debe ser apropiadamente conectado a tierra y cumplir con todas las regulaciones locales que apliquen.

### SISTEMA DE PODER/CARGA PROVISTO POR EL USUARIO

Si usted provee su propio sistema de poder/carga, usted tiene que estar seguro, que el sistema proporciona el voltaje correcto y la corriente requerida por el EpiSensor bajo todo las condiciones de operación. Usted es responsable por la seguridad de su sistema de carga.

Si usted deriva energía de suministro principal, usted tiene que asegurarse que ha provisto un polo a tierra adecuado para todo el equipo. Si usted suministra sus propias baterías, siga las recomendaciones de seguridad del fabricante.

### CABLEADO Y POLO A TIERRA DEL SENSOR

En algunos casos el EpiSensor estará a una distancia lejos del registrador. En estas instalaciones existe la posibilidad de una elevada diferencia de potencial entre dos localidades de polo a tierra, debido ya sea a fallas en el alambrado del AC o corrientes de un extremadamente alto retorno de

tierra. Cuando el cable esta polarizado a tierra en uno de sus lados terminales, un voltaje potencialmente letal puede existir entre el otro lado terminal del cable y el polo a tierra. Considere este peligro durante la instalación y obtenga ayuda de un electricista calificado si este peligro existe.

#### **NO OPERE EN ATMÓSFERAS EXPLOSIVAS**

El EpiSensor no proporciona *ninguna protección explosiva* para descargas estáticas componentes que generen arcos eléctricos. *No operar* el equipo en una atmósfera de gases explosivos.

# Sécurité

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## Symboles & Terminologie

Les *symboles* suivant peuvent figurer sur les équipements Kinemetrics ou dans ce manuel:



Signifie *Attention!* Quand vous rencontrez ce symbole sur un instrument, veuillez vous référer à la section de ce manuel signalée par la même marque. *Avant* même d'effectuer la première opération sur l'instrument, vous devez lire la section correspondante de ce manuel. Faites attention si vous voyez cet symbole.



Indique une mise à la terre "faible bruit". Les objets portant cette marque doivent être reliés à la terre afin d'assurer un fonctionnement optimal. Elle est aussi utilisée pour les éléments de protection contre les interférences magnétiques, les perturbations hautes fréquences radio et contre les surtensions. Cette mise à terre *n'est pas une mise à terre de sécurité* pour une protection contre les chocs électriques!



Indique une *alimentation en courant alternatif (AC)*.



Indique une Alimentation en courant continu (DC) dérivée d'une alimentation alternative



Indique la présence d'un *composant sensible aux décharges électrostatiques (ESD)*, Cela signifie qu'il faut observer toutes les précautions d'usage en manipulant ce composant.

Les *termes* suivant apparaissent dans ce manuel:

**Note:** Indique la présence d'une information que vous devez particulièrement considérer avant de passer à la prochaine instruction or operation.

**Caution:** Indique une condition ou opération qui peut entraîner des dommages à votre équipement, au logiciel ou à d'autres propriétés .

**WARNING!** Indique une condition ou opération qui peut entraîner des blessures corporelles ou la perte de la vie.

Les deux derniers termes mentionnés peuvent apparaître sur les équipements de Kinometrics que vous avez acquis, mais pas nécessairement — indifféremment, il est conseillé de prendre au sérieux les avertissements de ce manuel.

## Précautions Spécifiques

Observez toutes les précautions suivantes afin d'assurer votre sécurité personnelle et d'éviter des dégâts aux composants de votre capteur EpiSensor.

### ALIMENTATION

Le EpiSensor doit être alimenté avec un courant de  $\pm 12-15$  VDC fourni par l'enregistreur ou par votre propre système d'alimentation.

Si vous alimentez le EpiSensor avec l'enregistreur, connectez l'enregistreur en utilisant le système d'alimentation fourni par Kinometrics, et décrit dans le manuel d'utilisation délivré avec l'enregistreur.

Pour fournir une alimentation au EpiSensor, vous avez besoin d'une source à faible bruit  $\pm 12-15$  V avec une mise à la terre adéquate et qui remplit les conditions de la réglementation locale.

### OPTION SYSTÈME D' ALIMENTATION FOURNI PAR L'UTILISATEUR

Si vous fournissez votre système d'alimentation, vous devez vous assurer que le système fournit une tension et un courant requis par le EpiSensor. Veuillez noter que vous serez seul responsable pour la sécurité de votre système d'alimentation. Si vous utilisez le courant du réseau d'alimentation principal, vous devez vous assurer d'installer les mises à la terre adéquates pour tout votre équipement. Si vous utilisez vos batteries, vous devez vous référer aux recommandations fournis par le fournisseurs.

### MISE À LA TERRE ET CONNECTION DU CAPTEUR



Dans certain cas, le capteur EpiSensor est installé à distance de l'enregistreur. Dans ces installations il est possible, soit à cause d'une connection défectueuse au système d'alimentation principale ou d'un fort courant de retour à la terre, pour une différence de potentiel qui existe

entre la mise à la terre aux deux locations. Quand le câble est mise à la terre d'un côté, une tension potentiellement fatale peut exister entre l'autre côté du câble et la terre. Considérez ce danger pendant l'installation et demandez l'aide d'un electricien si ce danger existe.

#### **NE PAS UTILISER EN ATMOSPHERE EXPLOSIF**

Le EpiSensor ne comprend pas de protection contre les explosions dues aux décharges statiques ou aux composants pouvant provoquer des arcs. Ne pas utiliser ces composants en présence de gaz explosifs.

# 1. Introduction

This document is the *User's Guide to EpiSensor Model FBA ES-U*, a single-axis acceleration sensor. Kinometrics also produces a triaxial EpiSensor FBA, the FBA ES-T, and the FBA ES-SB (shallow) and FBA ES-DH (HypoSensor) triaxial borehole packages. Kinometrics' strong motion accelerographs feature a triaxial EpiSensor Altus deck.

*This manual applies only to EpiSensor Model FBA ES-U.* For the sake of brevity, the instrument is referred to simply as the *EpiSensor*.

Kinometrics is committed to ensuring a successful installation. For assistance with planning, installation, operation or maintenance, contact Kinometrics at the locations listed in the front of this manual. Kinometrics also has an extensive Services Group that can install, maintain, and analyze the data from your EpiSensor.

This chapter provides an overview of the EpiSensor and inspection instructions.

---

## The EpiSensor ES-U

The EpiSensor is a uniaxial accelerometer optimized for earthquake recording applications. Inside the waterproof, anodized-aluminum housing is one EpiSensor force balance accelerometer module.

The EpiSensor has user-selectable full-scale recording ranges of  $\pm 4g$ ,  $\pm 2g$ ,  $\pm 1g$ ,  $\pm 1/2g$  or  $\pm 1/4g$ . Its bandwidth of DC to 200 Hz is a significant improvement over earlier generations of sensors. The output voltage levels are user-selectable at either  $\pm 2.5V$  or  $\pm 10V$  single-ended, or  $\pm 5V$  or  $\pm 20V$  differential.

The EpiSensor is normally powered with a  $\pm 12V$  or  $\pm 15V$  external DC power source. It is optionally available with a single  $+12V$  supply option.

Full specifications for the unit can be found in Chapter 6.

---

## Inspecting the EpiSensor

Carefully remove the EpiSensor from its shipping container.

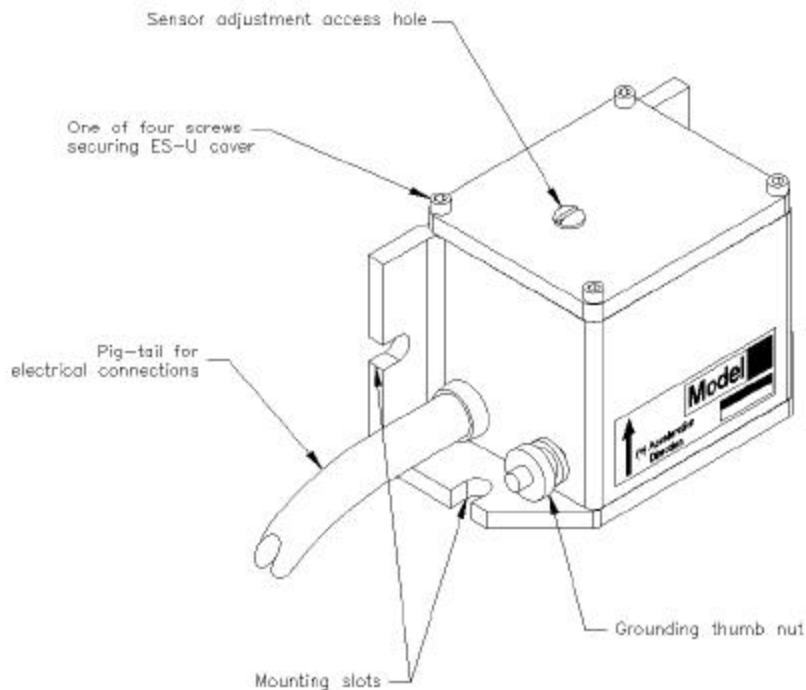
**Note:** If you expect to ship the EpiSensor again, save the shipping container and packing material.

Although Kinometrics takes every precaution in packing its systems, shipping damage can still occur. If you find a problem, note the condition of the shipping container. Then contact the freight forwarder and Kinometrics as soon as possible. Please contact Kinometrics before returning a damaged unit.

**Caution: Damage to sensors.** Dropping the EpiSensor onto a hard surface can damage the sensors.

---

**Figure 1: EpiSensor ES-U**



Examine the EpiSensor. The case should appear securely sealed, showing no sign of dents or scratches.

## 2. Installation Basics

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### Requirements for Installation

Listed below are the tools, supplies and equipment required to install the EpiSensor in a typical configuration (remotely from a Kinemetrics recorder, and attached to that recorder via a cable). However, certain installations may require additional tools, supplies or equipment, depending on specific sites and needs.

Refer to Chapter 6 for information on long cable runs and other advanced installation options.

These instructions assume that all civil engineering work (concrete pad, attachment plate, conduit, etc.) have been finished and that the EpiSensor has been correctly configured for your installation at Kinemetrics.

If you need to change the full-scale range output level, refer to Chapter 3 before proceeding.

### Required Tools

- Screwdrivers (1/8" flat blade, 1/4" flat blade)
- 5/64" or 2 mm hex ball driver (for zero adjustment)
- Long-nose pliers
- Wire strippers
- Soldering iron/heat gun (for installation with connector)
- AC-powered masonry percussion drill with 1/4" bit for drilling the anchor stud holes or fully charged battery-powered drill
- 7/16" open end wrench for 1/4-20 bolt

- Hammer
- Safety glasses

## Required Supplies

- Adequate length and appropriate type of cable for connecting the EpiSensor to the recorder. If a very long cable is required, refer to Chapter 6. We recommend Kinometrics P/N 700277 cable.

**Note:** If using non-Kinometrics cable, the signal should be sent in a shielded twisted pair, with five additional signal wires for the power and calibration control.

- Heat-shrink tubing (1/4" diameter), cable tie-wraps, and electrical tape
- Mating connector for units with optional connector
- Terminal strip, butt splices, or wire nuts for joining pigtail to main cable
- Two mounting anchors (provided)
- FerriShield (optional)

## Required Equipment

- Battery-powered digital volt meter (DVM)
- Compass for checking sensor orientation
- Camera to photograph the completed installations for the commissioning report (recommended)

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## Mounting & Orienting

Determine the location and orientation of the EpiSensor and which flange to use for mounting. The arrow on the EpiSensor case indicates the sensitive axis of the accelerometer.

Anchor the sensor to a concrete floor or slab or a secure, structural element such as a steel beam in a building as described below. An intermediate plate often provides an easier way of mounting to a structural concrete or steel beam.

**Note:** To accurately record strong ground motions of  $>0.1g$ , it is *essential* that the EpiSensor is anchored to the structure or slab. This is contrary to weak motion installations where sensors are just placed on the ground and leveled.

In weak motion, the weight of the instrument and friction between the feet and floor ensure accurate reproduction of ground motion. This is not the case at high acceleration levels, which can cause an unsecured instrument to move relative to the ground.

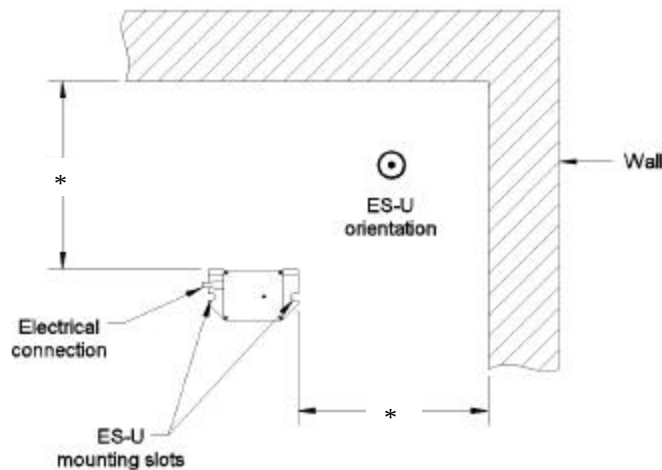
Keep a permanent record of the orientation. This information is crucial to the proper analysis of EpiSensor data.

Use the supplied mounting kit to attach the sensor to the mounting surface. The kit includes two heavy-duty wedge-type expansion anchor studs with 1/4-20 thread and a nut/washer unit.

Decide on the location of the EpiSensor, keeping in mind the working mounting dimensions.

*Important:* The anchor studs are 2-1/4" long and more than 1/2" must remain above the slab.

Follow all recommended safety precautions when using power tools. We recommend wearing safety glasses while drilling.

**Figure 2: EpiSensor mounting dimensions**

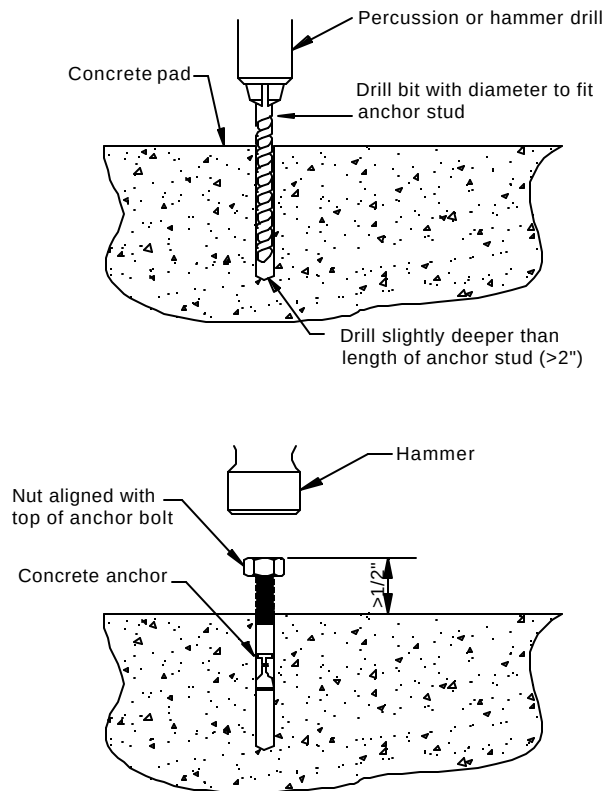
\*Allow sufficient clearance to drill holes and tighten mounting nuts.

1. Mark the position of the two mounting holes. The center of the two holes should be 3.5" (89 mm) apart.
2. Use a 1/4" (6.4 mm) masonry bit and drill to a depth of at least 1-3/4" with a percussion or hammer drill (if possible).
3. Clean debris out of the holes. (Blowing through a straw is an easy way to do this.)

**Note:** You may want to wrap a little masking tape 1-3/4" up from the point of the drill bit to mark how deeply to drill. The depth of the hole can be checked with a nail or narrow screwdriver. The hole should be vertical – *do not drill at an angle!*

4. Screw the nut/washers onto each stud until the top of the nut is flush with the top of the stud. This will make it easier to insert the studs and prevent damage to the threads.

**Note:** It is very important not to damage the threads of the anchor stud. Place a small piece of wood or similar object on top of the nut before tapping with the hammer. This will dissipate the energy between the stud/nut and the hammerhead and avoid damage to the threads.

**Figure 3: Drilling EpiSensor mounting holes**

5. **Gently** tap the top of each of the anchor studs with a hammer. The studs are now in position but not firmly seated. Carefully remove the nuts.
6. Place the EpiSensor mounting flange over the bolts and check that the orientation arrow is pointing in the correct direction. Place the washers and nuts on each of the studs and hand tighten.
7. Align the side of the EpiSensor case that is parallel to the orientation arrow carefully in the desired direction. This would normally correspond with a major axis of the structure or to the North-South or East-West orientation. For a sensor mounted on a horizontal surface, which is to sense vertical motion, the horizontal case orientation can be whatever is most convenient.

8. Tighten the stud nut with a 7/16" end-wrench and check the orientation. As you tighten the nuts, the studs will move slightly, forcing the locking cones to firmly grip the concrete. The final torque should be 20-26 inch/pounds (2.26-2.94 Nm).

**Note:** If you use a compass to determine the true north-south axis, be sure to correct for the difference between magnetic north indicated by the compass, and true north (magnetic declination). This deviation depends on your location; find the correct deviation on a local topographical map.

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## Connecting to the Data Logger

If you have purchased an optional connector and Kinometrics' mating cables, just connect the two cables and proceed to the next section.

If you are:

- Making your own cable,
- Using a cable that is longer than 1,000 feet (330 meters),
- Using a cable that has conductors thinner than 20 AWG,
- Or using the high-gain differential output,

read Chapter 6, *Advanced Installation*.

If you are connecting to the sensor pigtail, proceed with the following instructions:

### Pigtail Wiring

There are several ways to connect to the unit's pigtail:

- Use a terminal block that clamps directly to the wire, such as those made by Phoenix Contact.
- Attach spade terminals to the wiring by crimping or soldering and then use a screw terminal block for the connections
- Use small wire nuts (for temporary installations)

These connections must always be protected from moisture and physical damage. To prevent EMI/RFI from interfering with your installation it may be necessary to make these connections in a grounded metal box.

Make the connections using the wiring table below.

**Caution!** Incorrectly wiring these connections can result in serious damage to the EpiSensor or the attached recorder.

**Table 1: ES-U wiring**

| Pigtail Wire Color         | Optional Connector<br>KMI 851699 | Function            |
|----------------------------|----------------------------------|---------------------|
| Black wire in twisted pair | A                                | + signal            |
| White wire in twisted pair | B                                | – signal            |
| Twisted pair shield        | K                                | Signal shield       |
| Green                      | C                                | Cal coil            |
| Yellow                     | D                                | Cal coil enable     |
| Black                      | J                                | Power supply common |
| Brown                      | H                                | –12V                |
| Red                        | E                                | +12V                |
| White                      | F                                | No connection       |
| Outer shield               | G                                | Outer shield        |

In order to avoid confusion, please note that the pigtail contains:

- A twisted pair consisting of a black wire, a white wire and a shield inside a white insulation jacket
- A single black wire
- A single white wire

#### TWISTED PAIR TO INPUT CHANNEL

1. Connect the black wire in the twisted pair to the positive input channel of the recorder.
2. Connect the white wire in the twisted pair to the negative input channel of the recorder.
3. Connect the shield wire in the twisted pair to the recorder's ground for the channel to which the EpiSensor is connected.

## POWER CONNECTIONS

*In a dual supply EpiSensor (standard model):*

- Positive +12V/15V connects to the red wire
- Negative –12V/15V connects to the brown wire
- Common connects to the single black wire.

*In a single-supply EpiSensor (optional model):*

- +12/15V power connects to the red wire
- **No connection to the brown wire**
- Common connects to the black wire.

## CALIBRATION CONNECTIONS

Connect calibration signals to the appropriate outputs on the recorder.

## CONNECTING TO ALTUS EXTERNAL SENSOR INPUT

The table below shows, which pins the EpiSensor, should be connected to, on an Altus External Sensor Input Connector.

**Table 2: EpiSensor Outputs to Altus instrument channels**

|                      | Altus Instrument |             |             |
|----------------------|------------------|-------------|-------------|
|                      | 1st channel      | 2nd channel | 3rd channel |
| <b>Twisted pair:</b> |                  |             |             |
| Black wire (+)       | Pin L            | Pin A       | Pin C       |
| White wire (–)       | Pin M            | Pin B       | Pin D       |
| Shield wire          | Pin N            | Pin P       | Pin R       |

**Table 3: EpiSensor Connections to Altus external sensor connector**

| EpiSensor Pigtail             | Altus External Sensor Connector         |
|-------------------------------|-----------------------------------------|
| Green wire (cal coil output)  | Pin E                                   |
| Yellow wire (cal coil enable) | Pin F                                   |
| Outer shield                  | Pin U – (PGP or instrument case ground) |
| Single black wire             | Pin K (power supply common)             |
| Red                           | Pin J (positive power)                  |
| Brown or no connect           | Pin H (negative power)                  |

Read the following section on grounding for additional information. Chapter 6, *Advanced Installations*, contains additional information on connecting to recorders, grounding, etc.

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## Grounding the EpiSensor

Grounding sensitive instrumentation is a complex problem. It is difficult to give universally acceptable solutions for all installation types and site conditions because "grounding" has five goals – some of which can be mutually exclusive. These goals are:

- Prevent life threatening voltages in or on the equipment
- Immunity from EMI/RFI interference (susceptibility)
- Prevent radiation of EMI/RFI from the equipment (interference)
- Prevent damage to the equipment from lightning, ESD, etc.
- Low-noise operation

### Safety First

Obviously, the most important goal of any grounding scheme is to ensure the safety of people. Design and evaluate your grounding system with this in mind.

Since the EpiSensor contains no high voltage circuitry and is not connected to AC power, safety concerns arise from the recorder-end of the connection cable.

When using your own power system, be sure that AC power is fully isolated from the DC power supplied to the EpiSensor and that the power supply is safely grounded.

In its normal configuration, the EpiSensor is isolated from its case except for a high frequency EMI/RFI filter.



**WARNING! Potential lethal voltages.** Potentially lethal voltages can exist between the conductors on the cable or internal components, and the exposed metal case of the EpiSensor. These occur due to differences in ground potential between the location of the recorder and the location of the EpiSensor or faults in the recorder or user supplied power supply. *It is the user's responsibility to ensure that hazardous conditions are not created and that all local electrical safety regulations are observed.*

## EMI/RFI

To prevent EMI/RFI susceptibility and interference, an overall shield should be provided and cables must be carefully constructed to ensure shields terminate to the connector to provide a full 360° termination. This provides a low impedance path for high frequency noise to ground and does not allow high frequency to "leak" onto unprotected wiring in the cable.

The instrument's case and cable shields should generally be grounded to a low impedance earth ground.

The EpiSensor contains circuitry that will prevent damage from ESD transients.

Use the stainless steel screw on the flange of the instrument as the case ground connection point. To be effective, this point must be connected to a low impedance earth ground.

### **To provide low impedance connection to the ground:**

Attach the EpiSensor grounding screw to the ground with a heavy-gauge wire 3 mm in diameter (<10 AWG) or thicker, or a tinned copper braid at least 1.2 cm (1/2") in width.

To be effective this wire or braid should be as short as possible and have no sharp turns. The connection to the grounding point should have a large-area connection that is tightened and not subject to corrosion. Special clamps are available from electrical supply houses to make these connections.

In a building or structure where close lightning strikes are unlikely, a metallic water pipe, exposed section of re-bar, or an AC safety ground will probably be adequate.

*The Grounds for Lightning and EMP Protection* by Roger Block, second edition, published by Polyphaser Corporation provides an excellent practical discussion of grounding techniques.

## Low Noise Operation

This isolated configuration used for the EpiSensor will provide the lowest noise in the majority of installations. In these cases the power commons are tied to earth ground at a single location in the recorder. In high EMI environments, depending on the system configuration and noise source, the performance may be improved by connecting the power common to the case ground at the sensor. In this scheme ground loops can be created that degrade the low noise performance. If this occurs a possible solution is to create a hybrid ground. This can be done by connecting the power common to the case ground using a 0.1µF, 200V film capacitor.

In sites exposed to very high levels of EMI/RFI such as hilltop “Antenna Farms” additional EMI/RFI protection may be required. The Kinometrics Protection Enclosure (KMI P/N-110480)

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## Powering the EpiSensor

If possible, apply power to the system *without* connecting to the connector or pigtail on the EpiSensor and then verify that the power connections are correct.

Verify that:

- +12V is present on the wire that will connect to Pin E on the optional connector or the red wire in the pigtail
- –12V is present on Pin H of the optional connector or the brown wire in the pigtail
- The power common is connected to Pin J on the optional connector or the **single** black wire (power supply common) in the pigtail

In the *single supply EpiSensor option* verify that:

- +12V is present on Pin E on the optional connector or the red wire in the pigtail
- The power common is connected to Pin J on the optional connector or the **single** black wire (power supply common) in the pigtail
- Pin H is not connected

Switch the power source off and connect the cable or connector to the unit. Turn the power back on.

**Caution:** Connecting incorrect voltages or wrong polarities ( $> \pm 15.75\text{V}$ ) will seriously damage the EpiSensor.

---

## Zero-Adjusting the EpiSensor

After the EpiSensor has been installed and connected to the correct power, measure the DC offset. It should be as close as possible to zero so that the recorded data has minimal offset. With minimal offset the full range of the EpiSensor and recorder can be utilized.

## Methods of Measuring the DC Offset

If the EpiSensor is near the recorder, you may zero the accelerometer by using the recorder as if it were a DVM. If you are using an Altus recorder, use the AQ DVM command in QuickTalk's terminal mode.

If the EpiSensor is located at the end of a long cable, build a "break-out" cable to access and measure voltages in each of the wires in the EpiSensor cable. Be sure to supply the EpiSensor with  $\pm 12$  VDC or +12 VDC for the single power supply option.

## Performing the Zero Adjustment

Refer to Figure 1 to see the access screw that, when removed, provides access to the zero adjustment screw on the sensor module.

Naturally, it is impossible to achieve zero offset. The table below will tell you the acceptable range for DC offset for each possible ES-U configuration. (If desired, smaller offsets may be achieved with some patience.)

1. Remove the zero balance access screw on the top of the EpiSensor case.
2. Gently insert a hex ball (5/64" or 2 mm) wrench, *perpendicular to the case*, as far as it will go into the adjustment hole and make very minimal adjustments – counterclockwise for negative adjustments and clockwise for positive.
3. When the offset is in an acceptable range based on Table 2, carefully remove the hex wrench and replace the access hole screw.

**Important:** Give the unit a moderate tap with a screwdriver handle. The adjustment screw can have a residual stress that may cause an offset in data during a large earthquake. Tapping eliminates the residual stress.

**Note:** One turn changes the output by about 1g.

**Table 4: Reasonable zero offset voltages**

| Full-scale range | Single-ended<br>$\pm 2.5$ V output | Differential<br>$\pm 5$ V output | Single-ended<br>$\pm 10$ V output | Differential<br>$\pm 20$ V output |
|------------------|------------------------------------|----------------------------------|-----------------------------------|-----------------------------------|
| 1/4g             | 50 mV                              | 100mV                            | 200 mV                            | 400 mV                            |
| 1/2g             | 25 mV                              | 50mV                             | 100 mV                            | 200 mV                            |
| 1g               | 25 mV                              | 25mV                             | 50 mV                             | 100 mV                            |
| 2g               | 25 mV                              | 25mV                             | 25 mV                             | 50 mV                             |
| 4g               | 25 mV                              | 25mV                             | 25 mV                             | 25 mV                             |

## Note on Full-Scale Range

All full-scale ranges are stated as the voltage you would measure with a voltmeter between the + and – outputs for the sensor when full-scale acceleration is applied to the unit.

For example, with a differential output of  $\pm 20\text{V}$  on a range of  $1\text{g}$ , you would measure  $+20\text{V}$  if you applied  $1\text{g}$  to the sensor. In this case the positive output would be at approximately  $+10\text{V}$  with respect to ground, while the negative output would be at approximately  $-10\text{V}$  with respect to ground. If you applied  $-1\text{g}$  you would measure  $-20\text{V}$  between the outputs.



## 3. Operating Basics

The EpiSensor is designed as a very flexible low-noise accelerometer and can be configured to satisfy a wide variety of acceleration-sensing requirements.

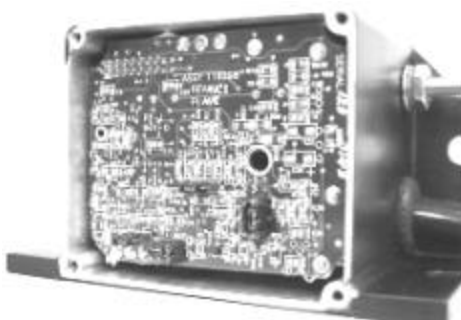
Configurable options include:

- Full-scale acceleration sensitivity of sensor – 1/4, 1/2, 1, 2, and 4g
- Single-ended or differential output
- Output voltage can be  $\pm 2.5\text{V}$  or  $\pm 10\text{V}$  single-ended
- Output voltage can be  $\pm 5\text{V}$  or  $\pm 20\text{V}$  differential

This chapter discusses:

- EpiSensor operation
- Polarity conventions
- How to configure operating modes
- Use of the calibration coil, which allows verification of the sensor's transfer function
- Power supply options

The photo shows the EpiSensor in its anodized-aluminum housing, which also includes:



- A sealed cover to prevent moisture and dirt from entering the instrument
- One access hole (covered by seal screws) through which zero offset may be adjusted
- A cable (visible at lower right, outside the housing) for the analog output voltages from the accelerometers and for supplying power and control signals to the EpiSensor

## Signal Polarity

Unlike previous generations of Kinometrics force balance accelerometers, the EpiSensor generates a positive output for acceleration in the direction of the orientation axis arrow on the housing. For information on polarity conventions, see Chapter 5, *Reference*.

## Required Power

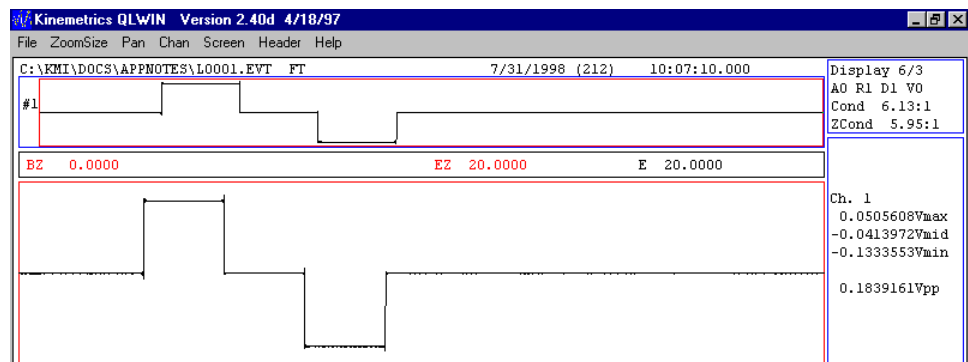
If you are using the EpiSensor with a Kinometrics Altus instrument, the +/-12V power will be supplied from the recorder.

If you are using another recording system you will need to supply the correct power. Refer to Chapter 6, *Advanced Installation Topics*, for more information.

## Performing a Functional Test with an Altus Recorder

Altus instrument firmware released after August 1, 1998 performs a dual polarity pulse test on EpiSensors as the standard functional test when correctly configured. This firmware is available at the Kinometrics website.

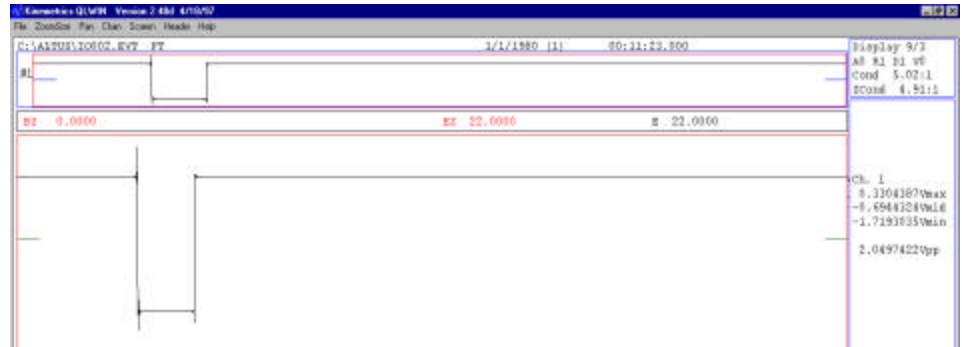
**Figure 4: Display of functional test**



The height of the pulse will depend on the full-scale setting of the instrument but will correspond to a g level of approximately 0.125g. The exact value will be 2.5V multiplied by the sensor module's calibration coil sensitivity value (which is provided on the sensor's data sheet).

Altus software released prior to August 1998 supports functional tests on the earlier generation of Kinemetrics force balance accelerometers but does not support the EpiSensor. If you perform a functional test or sensor response test on an EpiSensor using older software, the record will appear as in the screen below.

**Figure 5: Functional test using software released prior to August 1998**



The record looks like this because the calibration coil enable is only enabled during the undamped portion of the old FBA-11-style functional test

## Sensor Response Test

The sensor response test for the EpiSensor using Altus software released after August 1, 1998 measures the response of the sensor to white noise input. The digital-to-analog converter in the recorder drives the calibration coil with an analog voltage corresponding to a pseudo-random number sequence. The resulting file contains the information needed to compute the sensor response. For additional information on the sensor response test consult the Kinemetrics website.

## EpiSensor Configuration

This section describes how to configure the EpiSensor by placing 2-pin jumpers on specific headers on the oscillator board (located directly beneath the lid).

These jumpers are normally configured by Kinemetrics at the time of manufacture. If your EpiSensor is set to the correct range, the following instructions for re-configuring are unnecessary.

However, if you wish to change the settings, it is possible to do so in a laboratory environment.

*Kinometrics recommends that you do not attempt to change these jumpers in the field where debris or water could get into the unit.*

To access these jumpers and the headers to which they connect, the EpiSensor lid must be removed.

## Opening the EpiSensor Case



**Caution: Potential electrostatic discharge (ESD) hazard to equipment.**

Wear a grounded wrist strap with impedance of approximately 1 M  $\Omega$  when handling the EpiSensor circuit boards to protect components from damage.

1. Remove the four screws on top of the case.
2. Gently lift the lid off the EpiSensor.
3. Set the screws and the RFI gasket aside in a safe place.

## Jumper Selectable Options

The features that are controlled by the jumpers on the top board are:

- Full-scale range
- Output voltage level of 2.5V or 10V
- Differential or single-ended output

The jumpers can be installed or removed with tweezers or your fingers. Extra jumpers(KMI P/N 851152) can be obtained from Kinometrics if it is desired to set additional configurations.

## Setting the Full-Scale Range

The location of the various headers is shown in the following figures, which show jumper positions for various output options and ranges.

The following table shows the sensitivities available for the jumper-selectable ranges.

**Table 5: Range/sensitivity calculations**

| Full-scale range | Single-ended<br>$\pm 2.5\text{V}$ output | Single-ended<br>$\pm 10\text{V}$ output | Differential<br>$\pm 5\text{V}$ output | Differential<br>$\pm 20\text{V}$ output |
|------------------|------------------------------------------|-----------------------------------------|----------------------------------------|-----------------------------------------|
| 1/4g             | 10 V/g                                   | 40 V/g                                  | 20 V/g                                 | 80 V/g                                  |
| 1/2g             | 5 V/g                                    | 20 V/g                                  | 10 V/g                                 | 40 V/g                                  |
| 1g               | 2.5 V/g                                  | 10 V/g                                  | 5 V/g                                  | 20 V/g                                  |
| 2g               | 1.25 V/g                                 | 5 V/g                                   | 2.5 V/g                                | 10 V/g                                  |
| 4g               | 0.625 V/g                                | 2.5 V/g                                 | 1.25 V/g                               | 5 V/g                                   |

Voltage values are as measured across each channel's output pin, A and B. A is (+) and B is either (–) or ground depending on whether configured for a differential or single-ended connection to the recorder.

For best performance, a differential connection to the recorder should be used if the recorder supports differential input connections.

Figure 6 shows the jumper settings for the g-level of the sensor, which determines the full-scale range of the sensor. Figure 7 shows the jumper settings for the sensor output voltage.

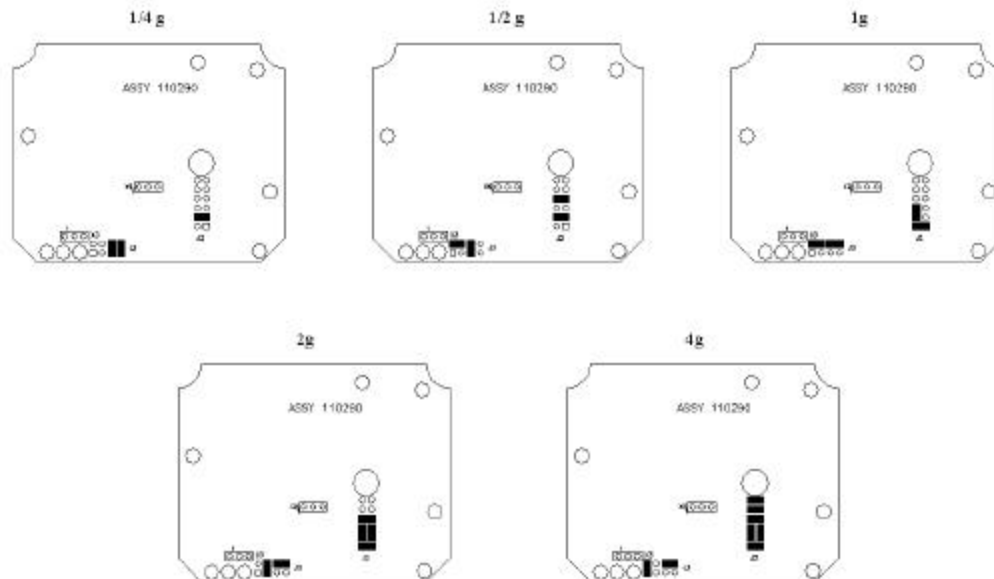
**Figure 6: Jumper settings for sensor g-level**

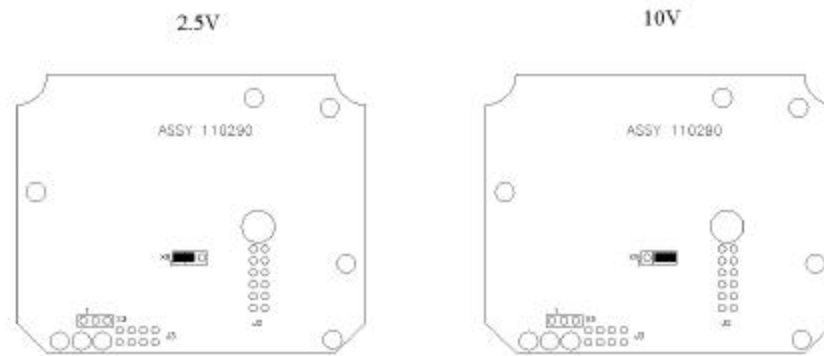
**Figure 7: Jumper settings for sensor output voltage**

Figure 8 shows the jumper settings for either single-ended or differential output configurations.

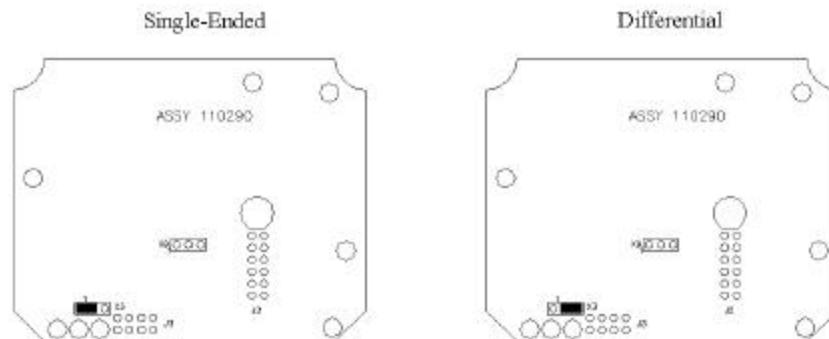
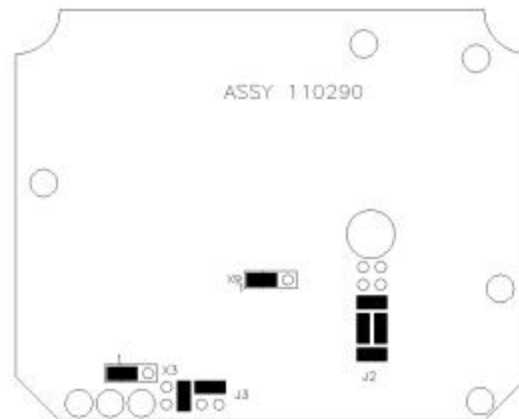
**Figure 8: Jumper settings for single-ended or differential output**

Figure 9 shows a sample of the most common setting, appropriate for many strong motion applications when the EpiSensor is used with an Altus recorder.

**Figure 9: Jumper settings for 2g, 2.5V, single-ended configuration**



Note that while the above settings are independent, each of the options must be configured correctly for the EpiSensor to function properly.

## Power Supply Options

The EpiSensor is offered in two power supply configurations:

- Dual-supply (standard)
- Single-supply (optional)

The jumpers for these options are set at the factory and should not be changed.

**Caution: Damage to instrument.** When the EpiSensor is configured for single-supply operation **do not** connect any power source to the brown wire or Pin H (on the connector).

## Calibration Coil

The EpiSensor is equipped with a calibration coil. This coil is isolated from other EpiSensor circuitry and accurately emulates the effect of acceleration on the system. This coil can be used to verify both the static acceleration sensitivity of the EpiSensor and the dynamic response of the system. When used with Altus recorders, the calibration signals are automatically applied

to the sensor. Access to the coil for calibration verification is discussed below.

With non-Altus recorders, access to the calibration coils is available through the cable. The cal coil is enabled by applying a +5 to +12 volt signal to the calibration coil enable line (CCE) that closes an electronic switch. This switch is normally open to prevent noise from entering the system.

The calibration coil sensitivity is provided in the data sheet of each unit. The total resistance to ground of the calibration coil line is about 1710 ohms; and the nominal resistance of the calibration coil is 110 ohms.

The additional resistance of approximately 1600 ohms added in series with the calibration coil is necessary as the coil is driven from a voltage source

## Closing the EpiSensor Case



**Caution: Potential electrostatic discharge (ESD) hazard to equipment.**

Wear a grounded wrist strap with impedance of approximately 1 M  $\Omega$  when handling the EpiSensor circuit boards to protect components from damage.

1. Inspect the gasket to make sure it is still elastic and is not torn.
2. Install gasket and cover over the housing.
3. Engage the four 4-40 socket head screws and tighten by hand.

**Note:** Make sure the gasket completely covers the gap between the cover and enclosure.

4. Make sure the gasket is properly installed closing the gap between the cover and enclosure.
5. Tighten screws to a torque of 5-6 inch-pound (0.56 – 0.77 Nm).
6. Re-inspect the gasket.

## 4. Maintenance

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### Recommended Maintenance

The EpiSensor is designed for many years of unattended use, but we recommend that you perform the following checks a minimum of once a year. If the EpiSensor is connected to an Altus recorder equipped with a modem, this maintenance check can be performed remotely and more frequently. See the Altus recorder manual for more details.

#### Adjust the Accelerometer

If the offset of the EpiSensor module measures more than the suggested limit shown in Table 1, it should be adjusted. Refer to *Chapter 2* for instructions on adjusting the zero offset.

#### Complete a Functional Test

Kinematics recommends that you perform a functional test on the accelerometer at each service visit to check that the unit is operational and as a baseline record for future visits. Refer to *Chapter 3* for instructions on performing the functional test.

If the unit is connected to a Kinematics recorder, refer to the recorder's manual for instructions on performing the functional test. Refer to *Chapter 6* if the unit is connected to a non-Kinematics data acquisition system.

#### Calibration

The EpiSensor is very stable and maintains its calibration in the field for many years. A functional test will provide a good indication of whether the sensor is working properly. A further quick check of the calibration can be performed by simply tilting the sensor  $+90^0$  and  $-90^0$  in each axis. By tilting the sensor, an acceleration of  $\pm 1g$  can be measured.

Kinometrics can supply a tilt table and training in order to perform more accurate calibrations/verifications in the field. Kinometrics can also provide on-site or factory calibrations traceable to national standards.

## Desiccant Replacement

The EpiSensor contains a small package of desiccant that is designed to maintain a low humidity level inside the unit. If the case is left open for a long time, opened repeatedly for inspection or adjustment, or in very humid conditions, the desiccant may be incapable of absorbing more moisture. This is indicated by the ink on the desiccant pack turning from its original blue to pink. When this happens it should be replaced.

New desiccant can be ordered from Kinometrics as P/N 700403. Be sure to follow electrostatic discharge (ESD) precautions when the sensor case is opened.

Instructions for opening and closing the EpiSensor case are provided in Chapter 3.



**Caution: Potential electrostatic discharge (ESD) hazard to equipment.**

Wear a grounded wrist strap with impedance of approximately  $1\text{ M}\Omega$  when handling the EpiSensor circuit boards to protect components from damage.

## Troubleshooting and Repair

If your EpiSensor does not appear to be working, we suggest you first check that the cabling and power supply are correct. If the problem persists we recommend you return the unit to Kinometrics for repair and re-calibration.

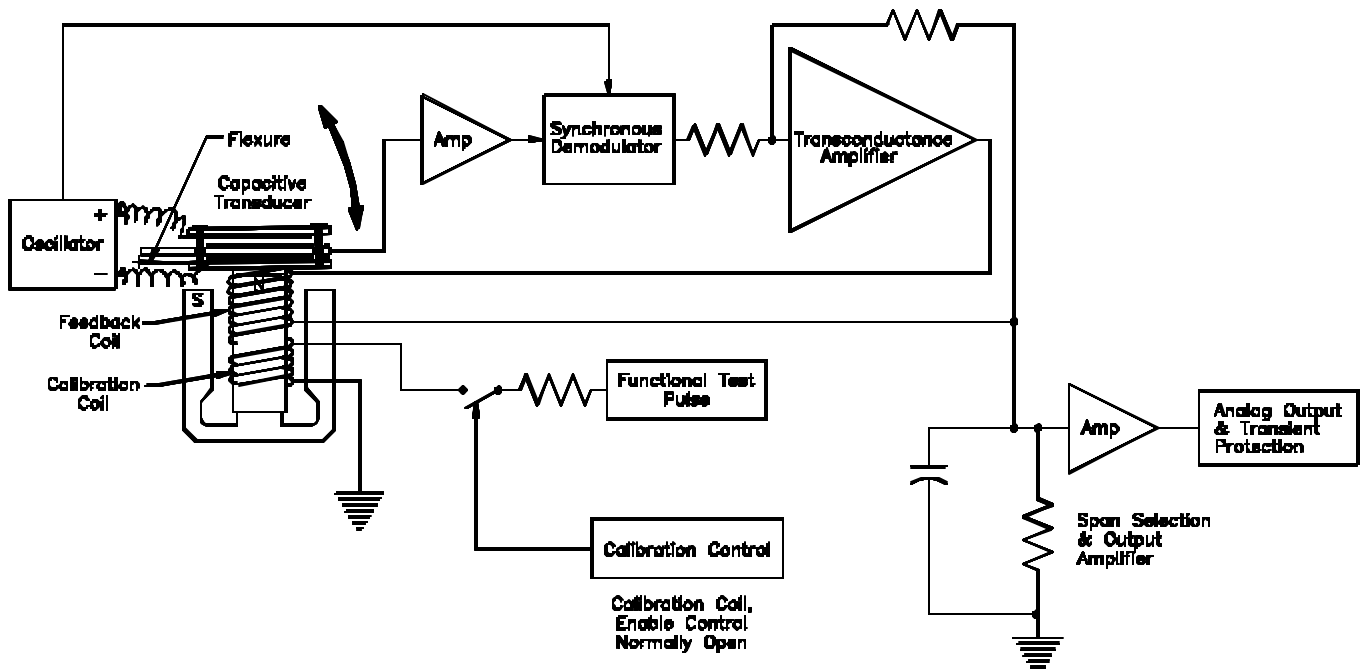
## 5. Reference

### Theory of Operation

The EpiSensor consists of a force balance accelerometer (FBA) inside a housing. The accelerometer module plugs into a board that provides the final output circuit and the carrier oscillator.

The figure below shows a simplified block diagram of the major components of an FBA.

Figure 10: Simplified block diagram of an accelerometer



## Working Principle

- The oscillator applies an AC signal of opposite polarity to the two moving capacitor plates (also referred to as "the moving mass"). When the accelerometer is "zeroed" and when no acceleration is applied, these plates are symmetrical to the fixed central plate and no voltage is generated.
- Acceleration causes the coil and capacitive sensor plates, which are a single assembly mounted on mechanical flexures (springs), to move with respect to the fixed central plate of the capacitive transducer.
- This displacement results in a signal on the center plate of the capacitor becoming unbalanced, resulting in an AC signal of the same frequency as the oscillator being passed to the amplifier.
- The amplifier amplifies this AC signal.
- This error signal is then passed to the demodulator where it is synchronously demodulated and filtered, creating a "DC" error term in the feedback amplifier.
- The feedback loop compensates for this error signal by passing current through the coil to create a magnetic restoring force to "balance" the capacitor plates back to their original null position.
- The current traveling through the coil is thus directly proportional to the applied acceleration. By passing this current through a complex impedance consisting of a resistor and capacitor, it can be converted to a voltage output proportional to acceleration with a bandwidth of approximately 200 Hz.
- Selecting a particular resistor value sets the full-scale range. The resistor values are determined by a high accuracy network, so the range can be set at 0.25g, 0.5g, 1g, 2g, and 4g without re-calibrating the sensor span.
- The capacitor and overall loop gain are selected along with the resistor to ensure an identical transfer function on each range. *This is why two sets of jumpers must be changed together to modify the range.*
- The voltage output of the resistor capacitor network is set at 2.5V for the acceleration value corresponding to the particular range. For example, with the 2g range, a 1g acceleration would cause a 1.25V output, on the 4g range, 1g would result in a 0.625V output.

This voltage is then passed into the amplifier:

- The amplifier amplifies this signal by either 1 or 4 (selected by jumpers) to give a single-ended output of either  $\pm 2.5\text{V}$  or  $\pm 10\text{V}$ . A precision resistor network also determines this gain value.
- A second amplifier is also present which inverts the signal from the first and can be connected to the negative output lead (via jumpers). This allows the unit to give a differential  $\pm 5\text{V}$  or  $\pm 20\text{V}$  to match the input to 24-bit digitizers.

## Features

- Each EpiSensor module is equipped with a calibration coil. Applying a current to this coil simulates the effect of an acceleration applied to the sensor. This provides a much more thorough check of the sensor's performance than older techniques that merely stimulate the feedback circuitry.
- The calibration coil is open circuit in normal use to prevent noise pick-up. To utilize the calibration coil remotely from outside the unit, the calibration coil enable signal must be activated by applying a DC voltage of +5V to +12V with respect to ground.
- A voltage signal applied to the calibration line with CCE active will cause the EpiSensor module to respond with an acceleration output of approximately 0.05 g per volt applied. The exact calibration coil sensitivity is provided on the data sheet of each module.
- All external connections are passed through transient protection. These elements protect the sensor from the effects of electrostatic discharge (ESD). Each line is also filtered to prevent the entry of electromagnetic interference or radio frequency interference (EMI/RFI) to the sensor.
- Optionally, the unit can be equipped with a +12V to  $\pm 12\text{V}$  converter module allowing the EpiSensor to be powered from a single 12-15V supply.

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## Pole Zero Representation of the EpiSensor

EpiSensor accelerometers are closed-loop, force-feedback sensors measuring the relative displacement of a moving mass (plates) with respect to the sensor case. The sensor's transfer function (TF) depends almost entirely on the electronic components rather than on the mechanical

components of the sensors. The influence on the transfer function of the mechanical damping, spring elements and internal RC low-pass filter in the trans-conductance amplifier stage within the closed-loop path of the sensor are negligible for most applications.

We have determined a good empirical model of the system, which uses two pairs of conjugate poles to represent the transfer function of the instrument. If this transfer function is corrected for the DC sensitivity of the sensor, the amplitude agreement is within  $\pm 0.5$  dB over the bandwidth of the sensor. The phase agreement is within  $\pm 2.5^\circ$  in the 0-100 Hz band and within  $\pm 5^\circ$  over the full bandwidth of the instrument. This model can be represented as:

$$\frac{V(s)}{A(s)} = \frac{k_1 * k_2}{(s - p_1)(s - p_2)(s - p_3)(s - p_4)}$$

where  $k_1 = 2.46 \times 10^{13}$

$k_2$  = Sensitivity of sensor in V/g (from Table 3-1)

$s$  is the Laplace transform variable

$p_1 = -981 + 1009i$  (Pole 1)

$p_2 = -981 - 1009i$  (Pole 2)

$p_3 = -3290 + 1263i$  (Pole 3)

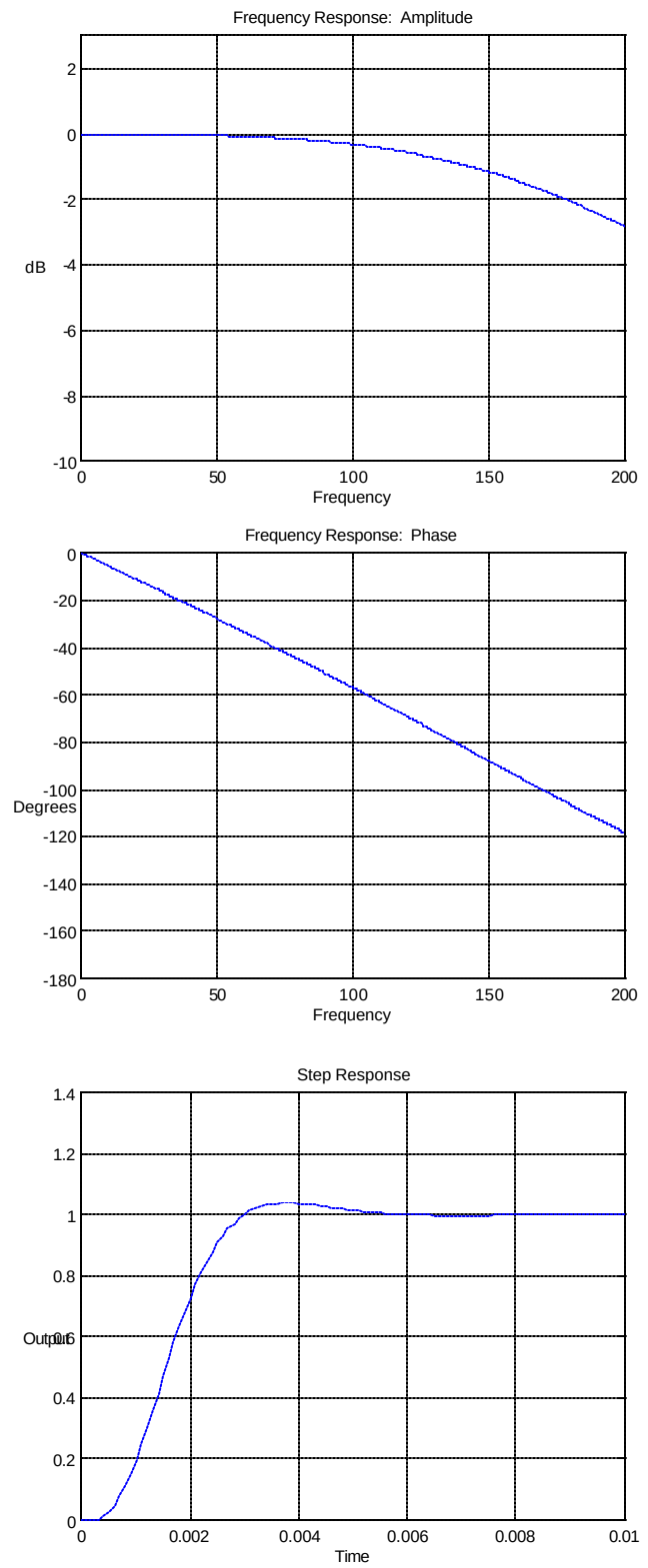
$p_4 = -3290 - 1263i$  (Pole 4)

$V(s)$  is the Laplace transform of the output voltage

$A(s)$  is the Laplace transform of the input acceleration

Figure 11 shows the amplitude, phase and step response of this pole zero representation.

Additional references to pole zero responses and damping are available on the Kinemetrics website. Application Note 39 gives the response of the FIR filters used in Altus Recorders. The FIR filters dominates the overall system response at sample rates of up to 250 samples per second

**Figure 11: Amplitude, phase, and step response**

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## Polarity Conventions

Unlike previous generations of Kinometrics force balance accelerometers, the EpiSensor has a positive output for acceleration along the sensitive axis.

Positive polarity is the international standard in weak motion seismology. With Kinometrics' decision to adopt a positive polarity with the EpiSensor FBA, it is now the standard in strong motion seismology as well.

Previous Kinometrics FBA designs produced a negative output for positive acceleration along each axis.

## 6. Advanced Installations

This chapter contains information on various advanced installation topics that may apply to your system. Kinemetrics' Service Group can provide additional information on these topics.

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### CE Compliant Installations

The EpiSensor has not yet been CE certified.

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### Using EpiSensors with Altus Instruments

This section discusses the use of the EpiSensor with Kinemetrics Altus Instruments.

#### The K2 & Mt. Whitney

The 4-Channel ADC/DSP board in a 4 Channel K2 can supply sufficient power for three ES-U's. The ES-U's should normally be configured as 2.5V single ended output units.

The 6-channel ADC/DSP boards used in the K2 and Mt. Whitney can supply 125 mA from the +12 and -12V power lines for the sensors and any gain boards. Gain boards draw approximately 5 mA from both power lines, and would normally not be used with an EpiSensor. The board supplies sufficient current for three ES-U units in any configuration even with gain boards. The board will also supply sufficient current for six ES-U's in the 2.5V single ended output configuration.

If you wish to use six ES-U units with a high-gain output, or a combination of ES-U's and other sensors you need to work out the current requirement as shown in Table 8. The total current for all sensors and gain boards must not exceed the 125mA limit.

If the configuration would exceed this limit, we suggest using one of the following solutions:

- Contact Kinometrics about modifying the ADC/DSP board to supply more power
- Use the single supply option on the EpiSensors, powering the units from the +12V battery power on the K2 or Mt. Whitney
- Build your own power supply unit

## The Etna

The Etna can supply power for two ES-Us configured as 2.5V single ended output units. When using three ES-U units, the EpiSensor will need either a separate power supply or should use its single supply option and take power from the Etna's +12V. This is because the Etna can supply only +/-40mA on each +12 and -12V power line.

The only reason to use the differential output with the Etna is to take advantage of its superior common-mode rejection in a high noise environment and in this case the unit can only power a single ES-U directly. For two or three units either a separate power supply or the single supply option powered from the Etna's +12V should be used.

## Makalu

The 3 Channel Makalu (formerly known as the Everest) recorder can power three ES-U's connected in any configuration, and the 6 Channel Makalu recorder can power six ES-U's in any configuration.

When connecting to the Makalu the units should be configured with the +/- 20V differential input to maximize system noise performance.

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## Long Cables

In its lowest power configuration (2.5V single-ended output), the EpiSensor can be used with the normal Kinometrics cable (P/N 700277) for distances up to 1,000 feet with a variety of instruments.

If the EpiSensor is used with an Altus recorder, this distance can be extended up to 2,000 feet. For cable runs of this length, we recommend installation in a grounded metal conduit. If the cable is not installed in its own conduit and maximum resolution is required, it should not be run alongside cables carrying heavy AC or transient currents.

Cable lengths must be reduced considerably for the high gain differential option. The EpiSensor requires a minimum operating voltage of 11.5V to be sure it can supply the +/-10V output with respect to ground. In the worst case, the standard Altus unit's power output is only 11.6V.

Note that this configuration will seldom be used with K2s, Mt.Whitneys, and Etnas, because the output does not match the 2.5V input of the recorder. It will be used with the Makalu, but in this case the worst-case power output from the Makalu is +/-13.5V giving a much greater allowed voltage drop of 2V.

Calculations for the 2g operating range are provided in the following tables. These figures are a conservative limit for all ranges except 4g. The 4g units require an additional 5mA of dynamic current.

**Table 6: Typical Cable Resistance Calculation**

| Sensor Type                                                  | EpiSensor low-power, 2g, 2.5V S/E |
|--------------------------------------------------------------|-----------------------------------|
| Sensor minimum operating voltage                             | 10.0 V                            |
| Maximum supply current                                       | 17 mA                             |
| Minimum supply voltage                                       | 11.6 V                            |
| Allowed cable voltage drop                                   | 1.6 V                             |
| One-way allowed cable drop                                   | 0.8 V                             |
| One-way allowed resistance at full-scale output ( $V = IR$ ) | 47 $\Omega$                       |

**Table 7: Typical Cable Length Calculation**

| Cable AWG | Cable Resistance per 1000 Feet | Low-power 2g, 2.5V Single-ended Maximum Cable Run in Feet |
|-----------|--------------------------------|-----------------------------------------------------------|
| 20        | 10.90 $\Omega$                 | 4300 feet                                                 |

## User-Supplied Cable

If you are using your own cable, be sure that it has sufficient conductors of the required wire gauge for the installation and that it provides adequate shielding to maintain the noise performance of the EpiSensor. The conductors used for the signals and the control signals (Cal and CCE) carry little current.

The previous section showed examples of the resistance and calculated voltage drop for a cable when using an Altus recorder. You can substitute your own values to calculate the allowed cable length for different configurations and cable wire gauges.

To calculate the maximum current for different EpiSensor configurations use Table 8.

To exceed these lengths, use a power supply that supplies more than 11.6V but less than 15V. Calculate the voltage drop in the cable at the maximum supply current and make sure that it meets the minimum operating voltage for the chosen configuration.



**WARNING! Potential lethal voltages.** With long cables, potentially lethal voltages can exist between the conductors on the cable or the exposed metal parts of the EpiSensor. These occur due to differences in ground potential between the location of the recorder and the location of the EpiSensor. Faulty electrical wiring returning large currents to ground normally causes these differences. *It is the user's responsibility to ensure that hazardous conditions are not created and that all local electrical safety regulations are observed.*

## Grounding



The cable assembly technique used for connecting the EpiSensor to an Altus instrument is designed to allow future compliance with the requirements of the emissions and immunity standards (EN 55022 Class A, EN 50082-2) of the European Community.

## Use with Non-Kinematics Data Loggers

If you are using the EpiSensor with a non-Kinematics data logger you must match the power, calibration and output of the EpiSensor with that of the recorder. Kinematics Services Group can provide help with this and can also supply conversion boxes to interface to some commonly used seismic instrumentation.

### Power Supply

The standard EpiSensor requires a well-regulated, low-noise  $\pm 12\text{V}$  ( $\pm 5\%$ ) or  $\pm 15\text{V}$  ( $\pm 5\%$ ) supply that can provide adequate current for the configuration you are using. The supply should be low-noise – less than 50 mV of ripple.

The single supply option can tolerate a relatively wide input range from 10 to 18 VDC. The supply should be low noise and have less than 100 mV of ripple to ensure low-noise performance of the sensor.



**Caution:** Incorrect power to the EpiSensor can cause incorrect readings and may damage the sensor. If the voltage is too low the EpiSensor will not attain its full-scale output and the data will be corrupted. Never supply more than  $\pm 15.75\text{V}$  to the unit and be sure the connections are the correct polarity. The EpiSensor has no protection against reversed polarity connections. Reversed power connections will severely damage the instrument!

The current required for the EpiSensor can be calculated using the table below. The supply should be capable of supplying the maximum load for the sensor under operating conditions. The quiescent current is the best figure to use for sizing batteries or solar charging systems.

**Table 8: ES-U Current Requirements**

|                                         |          |
|-----------------------------------------|----------|
| Quiescent                               | 12 mA    |
| Mass balance current                    | 2.5 mA/g |
| Additional current for high gain output | 6 mA     |

### Output Voltage

The EpiSensor output is user-selectable, as is the output amplifier. Select the EpiSensor output that matches the recorder input. If possible use a

differential input connection for optimum performance. Configuring the correct range and output is described in *Chapter 3*.

The output impedance of the EpiSensor is 50  $\Omega$  to ensure the unit is stable under capacitive loading from a long cable. Normally data loggers have an input impedance of 100 k $\Omega$  or more, so the 50 $\Omega$  output impedance is insignificant.

## Calibration Sequence

To produce a functional test sequence the recorder must control the Cal and CCE line to the EpiSensor.

Even if the recorder cannot produce a functional test it is still very important that these lines be held at the correct potential. The Cal line is not connected to the sensor unless the CCE line is active, but to provide the best noise performance it should not be left floating. We suggest that the Cal line be grounded to power common when the calibration coil is not in use.

The CCE line drives a transistor that operates an analog switch that connects the Cal line to the sensor module calibration coil. The transistor will turn on the analog switch at voltages between +5 to +12V. The transistor is not activated at voltages below 0.5V. This means a CMOS driver can drive the line or an open collector output pulled up to 12V.

A transistor-transistor logic (TTL) level will probably work if the sensor is close to the digitizer. It is very important that the CCE line is not enabled when the calibration feature is not in use and that it is not powered when the unit is not powered.

This is because the Cal line is connected to the sensor coil during the calibration sequence, which can result in additional noise. The easiest way to prevent problems from the CCE line is to connect it to the power common or the -12V supply.

To produce a functional test sequence, the data logger needs to control both the Cal and the CCE lines. The voltage applied to the Cal line should be limited to +/-10V. The sensor should reproduce any signal applied by the digitizer within the voltage limits and the bandwidth of the sensor. Thus, the calibration sequence can range from the simple pulses described below to single frequency sine waves or chirped sine signals.

Be certain that the Cal line is not active when the EpiSensor is not powered – this could damage the unit.

If the data logger cannot perform a functional test, a simple test box can be built to simulate the desired calibration sequence.

A suggested sequence is as follows:

1. Apply 0V to the Cal line
2. Turn CCE to +12V

3. Wait 2 seconds
4. Apply +2.5V to Cal for 2 seconds
5. Change Cal to -2.5V for 2 seconds
6. Change Cal to 0V for 2 seconds
7. Turn CCE off by connecting it to 0V

This will produce a positive pulse followed by a negative pulse.

**Caution:** The CCE line must not be enabled during normal operation – severely degraded noise performance can result. Applying voltage to the Cal line or the CCE line when the unit is not powered will result in damage. Applying voltage above the power supply lines to the Cal line or the CCE line will also damage the unit.

## Ground Loop Prevention

When the EpiSensor is used with non-Kinometrics digitizers it is essential that the ground connections be carefully planned in order to prevent ground loops. Please see the section in this chapter on grounding.

This is especially important when using a PC-based data acquisition system. We recommend using the differential output of the EpiSensor to prevent common mode problems. When using single-ended output, the signal return should be connected to the negative input of the analog front-end's differential or instrumentation amplifier and not to circuit common.

The common connection should return to the power supply through only one path. When using a separate mains power supply for the EpiSensor, be very careful that it does not provide a separate ground return through the AC mains ground to the data acquisition computer. Use a star ground configuration for your system with the EpiSensor power supply, data acquisition system and PC all grounded at the same point.

In our experience, most noise problems with any installation are normally a result of power grounding or cable shielding!

## EpiSensor ES-U Specifications

| Type                     | Triaxial force balance accelerometer                                                         |
|--------------------------|----------------------------------------------------------------------------------------------|
| Dynamic range            | 145 dB +                                                                                     |
| Bandwidth                | DC to 200 Hz                                                                                 |
| Calibration coil         | Standard                                                                                     |
| Full-scale range         | User-selectable at $\pm 0.25g$ , $\pm 0.5g$ , $\pm 1g$ , $\pm 2g$ or $\pm 4g$                |
| Output                   | User-selectable at: $\pm 2.5V$ and $\pm 10V$ single-ended; $\pm 5V$ , $\pm 20V$ differential |
| Zero adjust              | Access hole for simple, efficient adjustment                                                 |
| Linearity                | $< 1000\mu g / g^2$                                                                          |
| Hysteresis               | $< 0.1\%$ of full scale                                                                      |
| Cross-axis sensitivity   | $< 1\%$ (including misalignment)                                                             |
| Zero point thermal drift | $< 500\mu g / ^\circ C$                                                                      |
| Power consumption        | Quiescent current $< 12$ mA from $\pm 12V$                                                   |
| Mounting                 | Dual bolt for horizontal or vertical mounting                                                |
| Connection               | 1.0m pigtail with stripped and tinned ends for splicing or junction box termination          |
| Operating temperature    | $-20^\circ$ to $+70^\circ$ C ( $0^\circ$ to $160^\circ$ F)                                   |